Work Order ID 52127

September 16, 2009 2:27:10 PM

Item ID: D2917-1 **Accept** **Setup** **Start**

Revision ID: B **Stop**

Item Name: Saddle LH

Start Date: 09/30/2009 **Start Qty:** 10.00 **Cust Item ID:**

Required Date: 10/05/2009 **Req'd Qty:** 10.00 **Customer:**

Reference:

Approvals: **Process Plan:** MF **Date:** 09-09-16 **Tooling:** ______ **Date:** ______ **Run** **Start**

QC: ______ **Date:** ______ **SPC (Y/N):** ______ **Date:** ______ **Stop**

Sequence ID/ Work Center ID	Operation Description	Set Up/ Run Hours	Draw Number	Draw Rev.	Plan Code	Accept Qty	Reject Qty	Reject Number	Insp. Stamp

Draw Nbr	Revision Nbr
D2917	Rev B

Sequence ID/ Work Center ID	Operation Description	Set Up/ Run Hours		Accept Qty	Reject Qty	Reject Number	Insp. Stamp
100 HAAS 1 HAAS CNC vertical machine #1	HAAS CNC VERTICAL MACHINING #1 **Memo** Program batch number□Machine Step No 1 as per Folio FA436 and visually inspect as per Dwg D2917 & attached Dimension Sheet□Machine Step No 2 as per Folio FA436 and visually inspect as per Dwg D2917 & attached Dimension Sheet□Machine Step No 3 as per Folio	0.00 0.00	ML/ SS 09/09/30	10	Ø		PTO
110 Mill Conv Conventional Milling Machine	CONVENTIONAL MILLING MACHINE **Memo** Machine Keyway and inspect per Dwg D2917 & attached dimension sheet	0.00 0.00	ML/ SS 09/09/30	10	Ø		
120 QC Quality Control	QC2- Inspect parts off machine FAI/FAIB **Memo**	0.00 0.00	ML/ SS 09/09/30	10	Ø		

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: D2917-1 PAR #: ______ Fault Category: Prod-Machined Parts NCR: Yes No DQA: ______ Date: 05-10-13

Resolution: Accepted Disposition: Use as is QA: N/C Closed: ______ Date: 05-10-13

NCR: 52127		WORK ORDER NON-CONFORMANCE (NCR)						
DATE	STEP	Description of NC Section A	Corrective Action Section B Initial Chief Eng	Action Description Chief Eng	Sign & Date	Verification Section C	Approval Chief Eng	Approval QC Inspector
05.10.01	100	SADDLE-TO-XTUBE WALL IS 0.170 IN SOME AREAS QTY (4). Tool offset on angle slightly RC: operator error	05.10.01 per 051042	Acceptable per attached SR	09/10/02	M.A 09/10/02	05.10.01 per 051042	05-10-02

NOTE: Date & initial all entries

H:\FORMS\Quality Assurance\approved QA\NCRWO RevE

Work Order ID 52127

September 16, 2009 2:27:10 PM

Item ID: D2917-1

Accept

Setup **Start**

Stop

Revision ID: B

Item Name: Saddle LH

Start Date: 09/30/2009 **Start Qty:** 10.00

Required Date: 10/05/2009 **Req'd Qty:** 10.00

Cust Item ID:

Customer:

Reference:

Run **Start**

Stop

Approvals: **Process Plan:** ______________ **Date:** __________ **Tooling:** ____________ **Date:** __________

QC: ______________________ **Date:** __________ **SPC (Y/N):** __________ **Date:** __________

Sequence ID/ Work Center ID	Operation Description	Set Up/ Run Hours	Draw Number	Draw Rev.	Plan Code	Accept Qty	Reject Qty	Reject Number	Insp. Stamp
130 QC Quality Control	QC8- Inspect parts - second check **Memo**	0.00 0.00 G.A 09/10/02				10	∅		
140 HandFinish Hand Finishing	Chemical Conversion Coat per QSI005 4.1 BR 09-10-2 **Memo**	0.00 0.00				10			
150 Powdercoat Powder Coating	White Gloss(Ref:4.3.5.1) per QSI005 4.3-Alum **Memo** START TIME: 11:00 ☐OVEN TEMPERATURE: 320° ☐FINISH TIME: 11:30	0.00 M 112260. 0.00 BL 09-10-5.				20			

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________________ PAR #: _______ Fault Category: __________________ NCR: Yes No DQA: _____ Date: _________

Resolution: ____________________ Disposition: ____________________ QA: N/C Closed: __________ Date: _________

NCR:		WORK ORDER NON-CONFORMANCE (NCR)						
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

Work Order ID 52127

September 16, 2009 2:27:10 PM

Item ID: D2917-1

Revision ID: B

Item Name: Saddle LH

Accept

Setup **Start**

Stop

Start Date: 09/30/2009 **Start Qty:** 10.00

Required Date: 10/05/2009 **Req'd Qty:** 10.00

Cust Item ID:

Customer:

Reference:

Run **Start**

Stop

Approvals: **Process Plan:** ____________ **Date:** __________ **Tooling:** ____________ **Date:** __________

QC: ____________ **Date:** __________ **SPC (Y/N):** __________ **Date:** __________

Sequence ID/ Work Center ID	Operation Description	Set Up/ Run Hours	Draw Number	Draw Rev.	Plan Code	Accept Qty	Reject Qty	Reject Number	Insp. Stamp
160 QC Quality Control	QC3- Inspect Part Finish **Memo**	0.00 0.00				C 09/10/05			10
170 Packaging Packaging	Identify as per dwg & Stock Location:______ **Memo**	0.00 0.00				C 09/10/05			10
180 QC Quality Control	QC21- Final Inspection - Work Order Release **Memo**	0.00 0.00				09/10/06			

MF 09-10-05

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________________ **PAR #:** _______ **Fault Category:** __________________ **NCR:** Yes No **DQA:** _____ **Date:** _________

Resolution: ____________________ **Disposition:** ____________________ **QA: N/C Closed:** __________ **Date:** _________

NCR:		WORK ORDER NON-CONFORMANCE (NCR)						
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

Picklist Print

September 16, 2009 2:27:10 PM

Work Order ID: 52127

Parent Item: D2917-1RevB

Parent Item Name: Saddle LH

Start Date: 09/30/2009 **Required Date:** 10/05/2009

Comments:

Start Qty: 10.00 **Required Qty:** 10.00

Component Item ID/ Item Name	Replacement Item ID	Mfg/ Purch	Bin Item	Primary Location	Last Location	Route Seq ID	Unit of Measure	Qty on Hand	Remaining Qty To Pick	Qty Issued	Date Issued	Status
D6102-010RevD Saddle Billet		Manufactured	No			100	Each	6.0000	10.0000			

Warehouse Location	Loc Qty	Loc Code
Main Warehouse		
MAT	6	
51423	6	

52067 10 [illegible] 09/10/02

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________ **PAR #:** ______ **Fault Category:** ____________ **NCR:** Yes No **DQA:** _____ **Date:** ________

Resolution: ____________ **Disposition:** ____________ **QA: N/C Closed:** ________ **Date:** ________

NCR:		WORK ORDER NON-CONFORMANCE (NCR)						
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

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DART AEROSPACE LTD	Work Order:	52127
Description: Saddle LH	Part Number:	D2917-1
Inspection Dwg: D2917 Rev. A1		Page 1 of 1

Inspect dimensions highlighted on inspection sheet drawing D2917 Rev. A1 and record below:

				Recorded Actual Dimensions					
Dim	Min	Max	Go/No Go Gauge	1	2	3	4	By	Date
A	0.175	0.205		.195	.195	.185	.195		
B	0.090	0.110		.100	.100	.090	.090		
C	0.250	0.270		.268	.265	.265	.265		
D	1.599	1.619		1.612	1.612	1.615	1.615		
E	0.180	0.220		.180	.180	.180	.180		
F	0.277	0.297		.290	.290	.286	.291		
G	1.385	1.400		1.391	1.391	1.385	1.388		
H	3.170	3.230		3.206	3.206	3.205	3.205		
I	0.175	0.217	→	.180	.180	.169	.169		
J	0.470	0.530		.500	.500	.500	.500		
K	1.498	1.508		1.501	1.501	1.501	1.501		
L	4.436	4.446		4.442	4.440	4.441	4.440		
M	0.257	0.262	DT8683	.259	.259	.258	.258		
N	1.225	1.235		1.227	1.227	1.227	1.227		
O	1.103	1.113		1.108	1.108	1.108	1.108		
P	0.470	0.530		.500	.500	.500	.500		
Q	0.438	0.443	DT8682	.440	.440	.440	.440		
R	0.490	0.510		.504	.501	.502	.502		
S	1.745	1.755		1.750	1.750	1.750	1.750		
T	7.990	8.010		8.000	8.000	8.001	8.001		
U	3.495	3.505		3.500	3.498	3.499	3.500		
V	0.175	0.205		.185	.185	.178	.183		
2.000 → W	~~1.990~~	2.020		2.002	2.003	2.003	2.005		
X	0.760	0.765		.760	.760	.761	.760		
Y	0.307	0.312		.310	.310	.310	.310		
Z	0.615	0.635		.628	.629	.627	.627		
AA	0.177	0.197		.186	.189	.185	.182		
AB									
AC									
AD									
AE									
AF									
AG									
AH									
Accept/Reject									

Measured by:	LP		Audited by	G.A
Date:	09/09/20		Date:	09/10/02

Rev	Date	Change	Revised by	Approved
A	04.08.12	New Issue	KJ/JLM	
B	04.09.20	Added DT8683 & DT8682	KJ/JLM	

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________________ PAR #: _______ Fault Category: __________________ NCR: Yes No DQA: _____ Date: _________

Resolution: ____________________ Disposition: ____________________ QA: N/C Closed: __________ Date: _________

NCR:		WORK ORDER NON-CONFORMANCE (NCR)						
			Corrective Action Section B					
DATE	STEP	Description of NC Section A	Initial Chief Eng	Action Description Chief Eng	Sign & Date	Verification Section C	Approval Chief Eng	Approval QC Inspector

NOTE: Date & initial all entries

DART AEROSPACE LTD	Work Order:	52127
Description: Saddle LH	Part Number:	D2917-1
Inspection Dwg: D2917 Rev. A1		Page 1 of 1

Inspect dimensions highlighted on inspection sheet drawing D2917 Rev. A1 and record below:

				Recorded Actual Dimensions					
Dim	Min	Max	Go/No Go Gauge	~~1~~ 5	~~2~~ 6	3	4	By	Date
A	0.175	0.205		.197	.195	.195	.194		
B	0.090	0.110		.095	.097	.095	.100		
C	0.250	0.270		.265	.265	.264	.264		
D	1.599	1.619		1.614	1.614	1.615	1.616		
E	0.180	0.220		.180	.180	.180	.180		
F	0.277	0.297		.290	.293	.293	.290		
G	1.385	1.400		1.390	1.385	1.385	1.385		
H	3.170	3.230		3.203	3.203	3.203	3.200		
I	0.175	0.217		.176	.178	.180	.179		
J	0.470	0.530		.500	.500	.500	.500		
K	1.498	1.508		1.501	1.500	1.501	1.502		
L	4.436	4.446		4.439	4.441	4.442	4.440		
M	0.257	0.262	DT8683	.259	.259	.259	.259		
N	1.225	1.235		1.229	1.229	1.232	1.226		
O	1.103	1.113		1.108	1.106	1.106	1.107		
P	0.470	0.530		.500	.500	.500	.500		
Q	0.438	0.443	DT8682	.446	.440	.440	.440		
R	0.490	0.510		.500	.502	.500	.503		
S	1.745	1.755		1.750	1.750	1.750	1.750		
T	7.990	8.010		8.001	8.001	8.002	8.002		
U	3.495	3.505		3.500	3.750	3.750	3.750		
V	0.175	0.205		.188	.190	.190	.185		
W	1.990	2.010		2.005	2.003	2.002	2.004		
X	0.760	0.765		.762	.760	.760	.760		
Y	0.307	0.312		.310	.310	.310	.310		
Z	0.615	0.635		.627	.627	.626	.629		
AA	0.177	0.197		.185	.186	.183	.186		
AB									
AC									
AD									
AE									
AF									
AG									
AH									
Accept/Reject									

Measured by:	GMK	Audited by	YA
Date:	04/10/02	Date:	09/10/02

Rev	Date	Change	Revised by	Approved
A	04.08.12	New Issue	KJ/JLM	
B	04.09.20	Added DT8683 & DT8682	KJ/JLM	

Dart Aerospace Ltd

W/O:		WORK ORDER CHANGES					
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________ PAR #: ______ Fault Category: ____________ NCR: Yes No DQA: _____ Date: _______

Resolution: ____________ Disposition: ____________ QA: N/C Closed: _______ Date: _______

NCR:		WORK ORDER NON-CONFORMANCE (NCR)							
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

DART AEROSPACE LTD	Work Order:	52127
Description: Saddle LH	Part Number:	D2917-1
Inspection Dwg: D2917 Rev. A1		Page 1 of 1

Inspect dimensions highlighted on inspection sheet drawing D2917 Rev. A1 and record below:

				Recorded Actual Dimensions					
Dim	Min	Max	Go/No Go Gauge	#9	#10	3	4	By	Date
A	0.175	0.205		.190	.190				
B	0.090	0.110		.090	.090				
C	0.250	0.270		.265	.265				
D	1.599	1.619		1.615	1.615				
E	0.180	0.220		.180	.180				
F	0.277	0.297		.293	.291				
G	1.385	1.400		1.385	1.388				
H	3.170	3.230		3.202	3.203				
I	0.175	0.217		.180	.179				
J	0.470	0.530		.500	.500				
K	1.498	1.508		1.500	1.501				
L	4.436	4.446		4.441	4.440				
M	0.257	0.262	DT8683	.259	.259				
N	1.225	1.235		1.228	1.229				
O	1.103	1.113		1.106	1.109				
P	0.470	0.530		.500	.500				
Q	0.438	0.443	DT8682	.440	.440				
R	0.490	0.510		.502	.504				
S	1.745	1.755		1.750	1.750				
T	7.990	8.010		8.002	8.002				
U	3.495	3.505		3.500	3.500				
V	0.175	0.205		.191	.188				
W	1.990	2.010		2.001	2.004				
X	0.760	0.765		.760	.760				
Y	0.307	0.312		.309	.310				
Z	0.615	0.635		.626	.626				
AA	0.177	0.197		.183	.186				
AB									
AC									
AD									
AE									
AF									
AG									
AH									
Accept/Reject									

Measured by:	mk	Audited by	G. A
Date:	09/10/02	Date:	09/10/02

Rev	Date	Change	Revised by	Approved
A	04.08.12	New Issue	KJ/JLM	
B	04.09.20	Added DT8683 & DT8682	KJ/JLM	

Dart Aerospace Ltd

W/O:	WORK ORDER CHANGES						
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

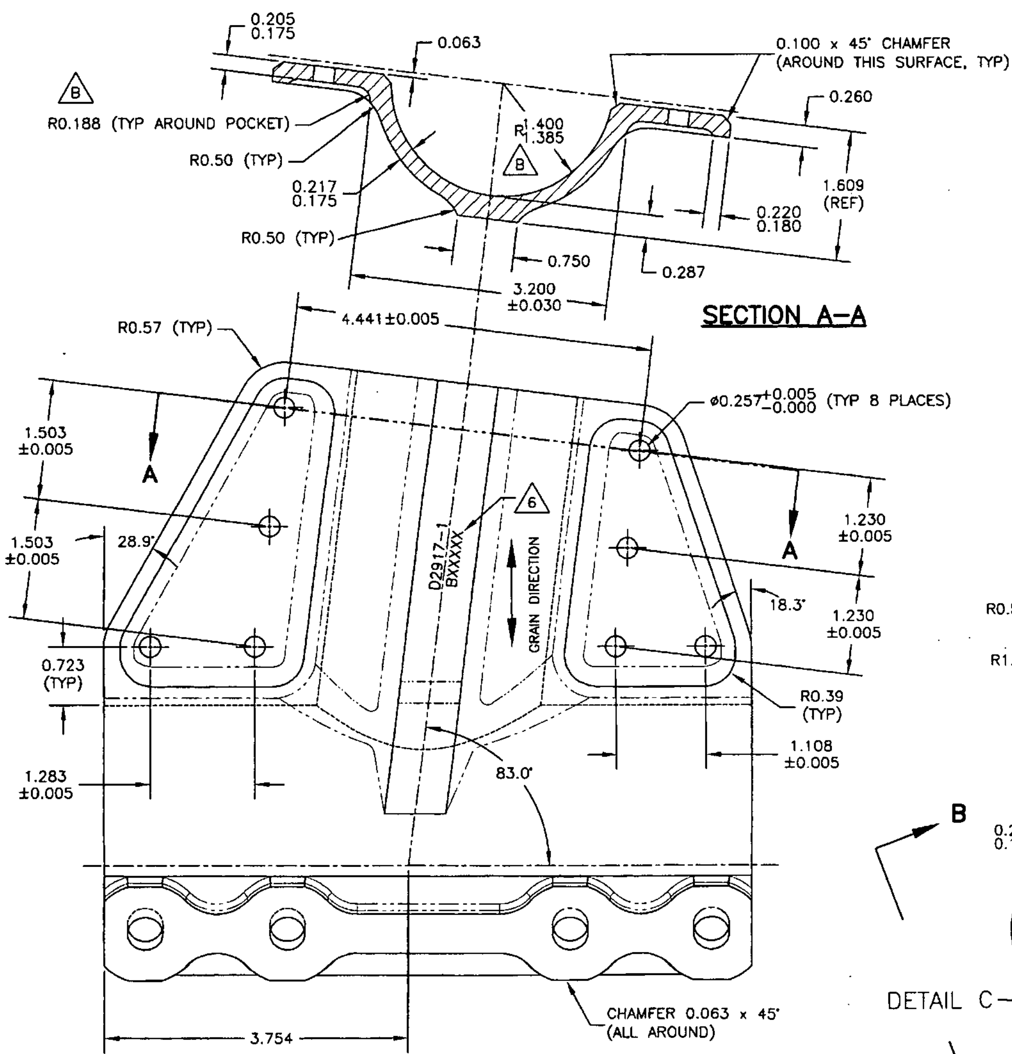
Part No: ____________ PAR #: ______ Fault Category: ____________ NCR: Yes No DQA: _____ Date: ________

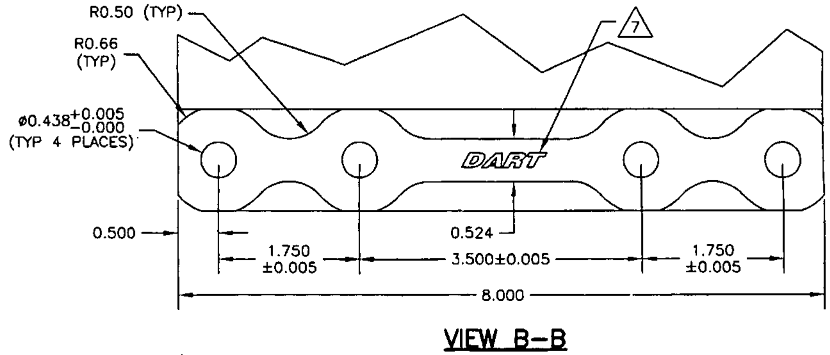
Resolution: ____________ Disposition: ____________ QA: N/C Closed: ________ Date: ________

NCR:	WORK ORDER NON-CONFORMANCE (NCR)							
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

H:\fFORMS\Quality Assurance\approved QA\NCRWO RevE

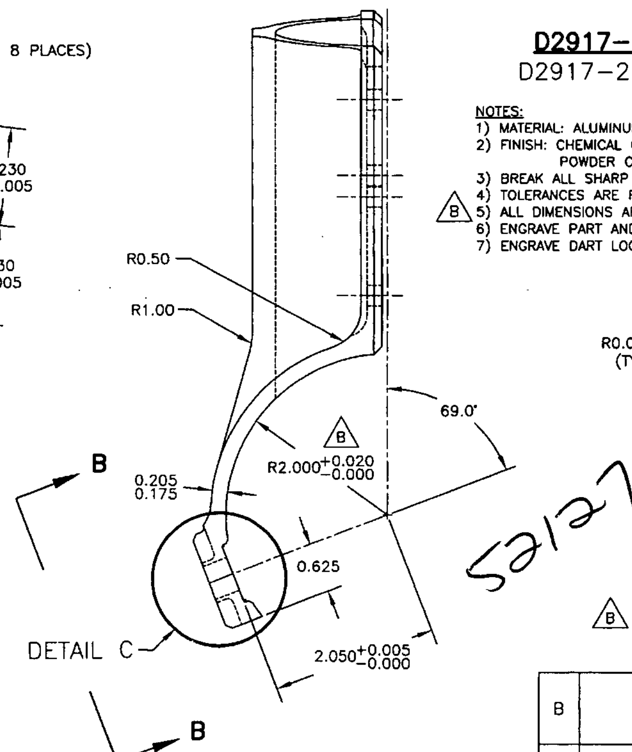


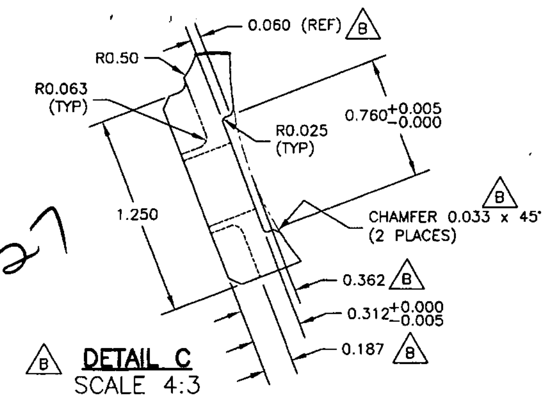


D2917–1 LH SADDLE (SHOWN)

D2917–2 RH SADDLE (OPPOSITE)

NOTES:
1) MATERIAL: ALUMINUM 6061–T6/T651 PER QQ–A–250/11
2) FINISH: CHEMICAL CONVERSION COAT PER DART QSI 005 4.1
POWDER COAT GLOSS WHITE (REF 4.3.5.1) PER DART QSI 005 4.3
3) BREAK ALL SHARP EDGES 0.010 TO 0.020
4) TOLERANCES ARE PER DART QSI 018 UNLESS OTHERWISE NOTED.
B 5) ALL DIMENSIONS ARE IN INCHES
6) ENGRAVE PART AND BATCH NUMBER IN THIS AREA TO MAX DEPTH OF 0.010
7) ENGRAVE DART LOGO TO MAX DEPTH OF 0.015 WITH MIN RAD 0.125





B	07.06.26	ADD 0.362, 0.187, 0.060, CHAMFER; ADD DETAIL C; R0.188 WAS R0.30; ADD TOL TO R2.000; ADD NOTES
A	04.05.31	NEW ISSUE

RELEASED
07.07.31

DESIGN	DRAWN BY CB	DART AEROSPACE LTD. HAWKESBURY, ONTARIO, CANADA
CHECKED PH	APPROVED	DRAWING NO. D2917 — REV. B — SHEET 1 OF 1
DATE 07.06.26		TITLE SADDLE — SCALE 2:3

Dart Aerospace Ltd

W/O:	WORK ORDER CHANGES						
DATE	STEP	PROCEDURE CHANGE	By	Date	Qty	Approval Chief Eng / Prod Mgr	Approval QC Inspector

Part No: ____________________ PAR #: _______ Fault Category: __________________ NCR: Yes No DQA: _____ Date: _________

Resolution: ____________________ Disposition: ____________________ QA: N/C Closed: __________ Date: _________

NCR:	WORK ORDER NON-CONFORMANCE (NCR)							
DATE	STEP	Description of NC Section A	Corrective Action Section B			Verification Section C	Approval Chief Eng	Approval QC Inspector
			Initial Chief Eng	Action Description Chief Eng	Sign & Date			

NOTE: Date & initial all entries

Excerpt from

5.0 Saddle Geometry

5.1 General Information

$ctubefwd := 1.388 \cdot in$	Fwd crosstube bore radius (see dwg D2917/D2918)
$ctubeaft := 1.50 \cdot in$	Aft crosstube bore radius (see dwg D2919/D2920)

5.2 Bell Saddles

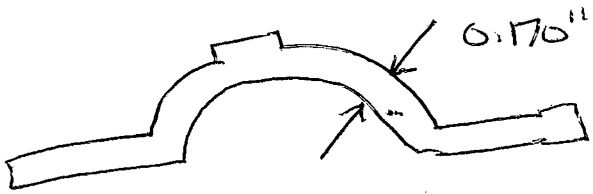
The forward and aft Bell saddles are one-piece aluminum forgings, part numbers 209-052-204-3 (fwd saddle) and 209-052-204-1 (aft saddle). Figure 3 in Reference 1 at the end of this report shows the Bell saddle geometry.

$n4 := 6$		Number of MS27039-4-13 screws in bearing & shear
$d4 := 0.250 \cdot in$		Diameter of MS27039-4-13 screws
$n5 := 8$		Number of MS27039-5-14 screws in bearing & shear
$d5 := 0.312 \cdot in$		Diameter of MS27039-5-14 screws
$tmatf := 0.125 \cdot in$		Fwd Bell forged saddle material thickness (minimum)
$tmata := 0.155 \cdot in$		Aft Bell forged saddle material thickness (minimum)
$ncb := 12$		Number of crosstube rivet bearing & shear areas
$dcb := 0.313 \cdot in$		Hole size for crosstube rivets
$Lb := 8.00 \cdot in$		Length of Bell saddles
$e := 0.5 \cdot in$		Edge distance for MS27039 screws
$e4 := e - d4$	$e4 = 0.25 \cdot in$	Tearout distance for MS27039-4-13 screws
$e5 := e - d5$	$e5 = 0.19 \cdot in$	Tearout distance for MS27039-5-14 screws

5.3 Dart Saddles

The geometry of a typical Dart saddle is illustrated in Figure 2 of Reference 1 at the end of this report. These dimensions have been taken from dwgs D2917-D2918, which are the replacement parts for 209-052-204-3, and dwgs D2918-D2919, which are the replacement parts for 209-052-204-1.

$nt := 8$		Number of skidtube bolt shear areas
$tw := 0.750 \cdot in$		Rib width
$tover := 0.245 \cdot in$		Overhang thickness
$wf := 0.750 \cdot in$		Skidtube flange width
$Df := 0.438 \cdot in$		Diameter of saddle flange bolt holes
$ef := \frac{wf - Df}{2} + tover$	$ef = 0.4 \cdot in$	Flange edge distance
$g := .125 \cdot in$		Gap between inboard-outboard saddles
$dcd := 0.313 \cdot in$		Hole size for crosstube bolts (see dwg D2917-D2920)
$ncd := 4$		Number of crosstube bolt shear areas
$txf := 0.265 \cdot in$		Fwd min. material thickness near saddle xtube bolt holes
$txa := 0.315 \cdot in$		Aft min. material thickness near saddle xtube bolt holes
$Ld := 8 \cdot in$		Length of Dart saddles
$tg := 0.313 \cdot in$		Thickness of saddle groove
$nf := 4$		Number of flange bolts each side of cross tube
$tf := 0.170 \cdot in$	WAS 0.175	Fwd minimum saddle material thickness
$ta := 0.225 \cdot in$		Aft minimum saddle material thickness
$trf := txf - tf$	$trf = 0.1 \cdot in$	Fwd rib thickness
$tra := txa - ta$	$tra = 0.09 \cdot in$	Aft rib thickness
$\mu := 0.8$		Conservative aluminum on aluminum friction co-efficient (see table on Page 12 of Reference 2)



7.0 Saddle Comparisons

A comparison between the fatigue curves for unnotched 2014-T6 material vs. unnotched 6061-T6 material shows that the 6061-T6 material used in Dart saddles is better than the 2014-T6 material used in Bell saddles (see Ref 2 Pages 9 and 10b). A reduction factor of 0.65/0.74=0.88 will therefore be applied in comparing Bell saddle material allowables to Dart saddle material allowables.

$ff := 0.88$ Fatigue factor

7.1 Lower Saddle Strength Comparison

The lower section of the Dart saddle is the same for both the D2917/D2918 forward saddle and the D2919/D2920 aft saddle.

$Ads := 2 \cdot tg \cdot (Ld - 4 \cdot Df)$	$Ads = 3.91 \cdot in^2$	Area of Dart saddle in tension/compression
$Abf := 2 \cdot tmatf \cdot (Lb - 4 \cdot d4 - 2 \cdot d5)$	$Abf = 1.59 \cdot in^2$	Area of fwd Bell saddle in tension/compression
$Aba := 2 \cdot tmata \cdot (Lb - 4 \cdot d4 - 2 \cdot d5)$	$Aba = 1.98 \cdot in^2$	Area of aft Bell saddle in tension/compression

Ultimate Tensile Strength

$Ftud := Ftu3 \cdot Ads$	$Ftud = 164272 \cdot lb$	Dart allowable ultimate tensile force
$Ftubf := Ftu4 \cdot Abf \cdot ff$	$Ftubf = 91177 \cdot lb$	Fwd Bell allowable tensile force (ultimate)
$Ftuba := Ftu4 \cdot Aba \cdot ff$	$Ftuba = 113059 \cdot lb$	Aft Bell allowable tensile force (ultimate)
$MS1f := \frac{Ftud}{Ftubf} - 1$	$MS1f = 0.80$	Margin of Safety - Dart fwd saddle (lower section) in tension (ultimate)
$MS1a := \frac{Ftud}{Ftuba} - 1$	$MS1a = 0.45$	Margin of Safety - Dart aft saddle (lower section) in tension (ultimate)

Compressive Yield Strength

$Fcyd := Fcy3 \cdot Ads$	$Fcyd = 136894 \cdot lb$	Dart allowable compressive force (yield)
$Fcybf := Fcy4 \cdot Abf \cdot ff$	$Fcybf = 82760 \cdot lb$	Fwd Bell allowable compressive force (yield)
$Fcyba := Fcy4 \cdot Aba \cdot ff$	$Fcyba = 102623 \cdot lb$	Aft Bell allowable compressive force (yield)
$MS2f := \frac{Fcyd}{Fcybf} - 1$	$MS2f = 0.65$	Margin of Safety - Dart fwd saddle (lower section) in compression (yield)
$MS2a := \frac{Fcyd}{Fcyba} - 1$	$MS2a = 0.33$	Margin of Safety - Dart aft saddle (lower section) in compression (yield)

Tensile Yield Strength

$Ftyd := Fty3 \cdot Ads$	$Ftyd = 136894 \cdot lb$	Dart allowable tensile force (yield)
$Ftybf := Fty4 \cdot Abf \cdot ff$	$Ftybf = 78552.32 \cdot lb$	Fwd Bell allowable tensile force (yield)
$Ftyba := Fty4 \cdot Aba \cdot ff$	$Ftyba = 97405 \cdot lb$	Aft Bell allowable tensile force (yield)
$MS3f := \frac{Ftyd}{Ftybf} - 1$	$MS3f = 0.74$	Margin of Safety - Dart fwd saddle (lower section) in tension (yield)
$MS3a := \frac{Ftyd}{Ftyba} - 1$	$MS3a = 0.41$	Margin of Safety - Dart aft saddle (lower section) in tension (yield)

Shear Strength

$Fsd := Ads \cdot Fsu3$	$Fsd = 105604 \cdot lb$	Dart allowable shear force (ultimate)
$Fsbf := Abf \cdot Fsu4 \cdot ff$	$Fsbf = 56109 \cdot lb$	Fwd Bell allowable shear force (ultimate)
$Fsba := Aba \cdot Fsu4 \cdot ff$	$Fsba = 69575 \cdot lb$	Aft Bell allowable shear force (ultimate)
$MS4f := \frac{Fsd}{Fsbf} - 1$	$MS4f = 0.88$	Margin of Safety - Dart fwd saddle (lower section) in shear (ultimate)
$MS4a := \frac{Fsd}{Fsba} - 1$	$MS4a = 0.52$	Margin of Safety - Dart aft saddle (lower section) in shear (ultimate)

7.2 Saddle to Skidtube Fastener Comparison

In order to compare the fasteners holding the saddles onto the skidtube, the fastener shear strengths, the shear tear-out of the saddle material, and saddle material bearing allowables must be considered. The margin of safety comparison will then be completed by comparing the weakest link of each configuration.

Fastener Shear Strengths

Dart saddles are held onto the skidtube with 4 AN4 bolts and D2570 stainless steel bushings. Additionally, the Dart system has a redundant load path for attaching the saddle to the skidtube. The saddle is configured to interlock over a flange on the extruded Dart skidtube.

The strength of the bolt and bushing combination is calculated as follows:

$Db := 0.257 \cdot in$		D2570 stainless steel bushing hole size
$Fsubush := 50000 \cdot lb \cdot in^{-2}$		Bushing material shear strength (Ref. 2 Pg. 13)
$Abush := \frac{\pi}{4} \cdot \left(Df^2 - Db^2\right)$	$Abush = 0.1 \cdot in^2$	Bushing area
$Fbush := Fsubush \cdot Abush$	$Fbush = 4939.96 \cdot lb$	Bushing allowable shear force
$Ffast := Fbush + FsuAN4$	$Ffast = 8619.96 \cdot lb$	Total shear force through bolt and bushing

Shear failure of the fasteners holding the Dart saddles onto the skidtube occurs when the bolts and bushings as well as the ridge on the outside of the skidtube fails.

$As := wf \cdot Ld - \pi \cdot Df^2$	$As = 5.4 \cdot in^2$	
$Fflange := 2 \cdot Fsu1 \cdot As$	$Fflange = 280660 \cdot lb$	
$Ftot := Ffast \cdot nt + Fflange$	$Ftot = 349619 \cdot lb$	Dart allowable shear force

Shear failure of the fasteners holding the Bell saddles and skidtube occurs when the rivets holding the saddles onto the skidtube fail.

$Friv := n4 \cdot FsuAN4 + n5 \cdot FsuAN5$	$Friv = 68080 \cdot lb$	Bell allowable shear force

Shear Tear-out of the Saddle Material

Shear tearout of the Dart configuration occurs when the bolts and bushings tear through the ridge and when the ridge tears off the saddle.

$Fdtear := Fsu3 \cdot (2 \cdot nt \cdot ef \cdot tg + 2 \cdot Ld \cdot tover)$	$Fdtear = 160062 \cdot lb$	Dart tear-out force

Shear tearout of the Bell configuration occurs when the MS27039-4/MS27039-5 bolts tear through the saddle material.

$Fbtear1 := Fsu4 \cdot ff \cdot tmatf \cdot (2 \cdot n4 \cdot e4 + 2 \cdot n5 \cdot e5)$	$Fbtear1 = 26435 \cdot lb$	Bell tear-out force of fwd saddle
$Fbtear2 := Fsu4 \cdot ff \cdot tmata \cdot (2 \cdot n4 \cdot e4 + 2 \cdot n5 \cdot e5)$	$Fbtear2 = 32780 \cdot lb$	Bell tear-out force of aft saddle

Bearing of the Fasteners on the Saddle Material

$Abf := 2 \cdot tflange \cdot Ld$	$Abf = 0.80 \cdot in^2$	Bearing area of Dart saddles

Ultimate Bearing Allowable

$Bud := nt \cdot Df \cdot tg \cdot Fbru3 + Fbru1 \cdot Abf$	$Bud = 162114 \cdot lb$	Dart allowable bearing force (ultimate)
$Bub1 := (n4 \cdot d4 + n5 \cdot d5) \cdot Fbru4 \cdot tmatf \cdot ff$	$Bub1 = 54066 \cdot lb$	Bell allowable bearing force (fwd, ultimate)
$Bub2 := (n4 \cdot d4 + n5 \cdot d5) \cdot Fbru4 \cdot tmata \cdot ff$	$Bub2 = 67042 \cdot lb$	Bell allowable bearing force (aft, ultimate)

Yield Bearing Allowable

$Byd := nt \cdot Df \cdot tg \cdot Fbry3 + Fbry1 \cdot Abf$	$Byd = 111612 \cdot lb$	Dart allowable bearing force (yield)
$Byb1 := (n4 \cdot d4 + n5 \cdot d5) \cdot Fbry4 \cdot tmatf \cdot ff$	$Byb1 = 39560 \cdot lb$	Bell allowable bearing force (fwd, yield)
$Byb2 := (n4 \cdot d4 + n5 \cdot d5) \cdot Fbry4 \cdot tmata \cdot ff$	$Byb2 = 49055 \cdot lb$	Bell allowable bearing force (aft, yield)

Margin of Safety

The above analysis shows that the Bell saddles will fail in shear tear-out before the fasteners fail or the saddles fail in bearing. The Dart saddles will fail in bearing before they fail in shear tear-out or before the fasteners fail.

$MS5f := \dfrac{Byd}{Fbtear1} - 1$	$MS5f = 3.22$	Margin of Safety - Dart fwd saddle-to-skidtube fastener failure
$MS5a := \dfrac{Byd}{Fbtear2} - 1$	$MS5a = 2.40$	Margin of Safety - Dart aft saddle-to-skidtube fastener failure

7.3 Saddle to Crosstube Fastener Strength Comparison

In order to compare the fasteners holding the saddles onto the crosstubes, the fastener shear strengths and saddle material bearing allowables must be considered. The margin of safety comparison will then be completed by comparing the weakest link of each configuration.

A significant advantage of the Dart saddle clamping system is that the friction between the saddle and the crosstube reduces the load transferred to the bolts to resist twisting moments. The installation instructions include torquing instructions to ensure that this friction load carrying capability is developed The method used to calculate this friction force is outlined in Figure 4 of Reference 1.

$Fa := 3130 \cdot lb$		Axial force per flange bolt
$Fmax := 0.9 \cdot nf \cdot Fa$	$Fmax = 11268 \cdot lb$	Total force exerted by all flange bolts
$N := 2 \cdot \pi \cdot Fmax$	$N = 70798.93 \cdot lb$	Normal force on crosstube
$Ff := \mu \cdot N$	$Ff = 56639.15 \cdot lb$	Friction force between saddle and crosstube

Fastener Shear Strength

Dart saddles are held onto the crosstubes with 2 AN5 through-bolts and the friction force that is created by bolting the 2 halves of the saddles together.

$Fsd := Ff + ncd \cdot FsuAN5$	$Fsd = 79639 \cdot lb$	Twisting force allowed before Dart saddle to crosstube bolts fail in shear

Bell saddles are held onto the crosstubes with 12 MS90354-1006 rivets but there is no friction force to resist twisting moments between the skidtube and the crosstube.

$Fsb := ncb \cdot Fsu1006$	$Fsb = 102000 \cdot lb$	Twisting force allowed before Bell saddle to crosstube rivets fail in shear

Bearing of the Fasteners on the Saddle Material

Ultimate Bearing Allowable

$Bud := Ff + ncd \cdot dcd \cdot txf \cdot Fbru3$	$Bud = 85836 \cdot lb$	Twisting force allowed before Dart saddles fail in bearing (ultimate)
$Bub1 := ncb \cdot dcb \cdot tmatf \cdot Fbru4 \cdot ff$	$Bub1 = 50819 \cdot lb$	Twisting force allowed before Bell fwd saddles fail in bearing (ultimate)
$Bub2 := ncb \cdot dcb \cdot tmata \cdot Fbru4 \cdot ff$	$Bub2 = 63015 \cdot lb$	Twisting force allowed before Bell aft saddles fail in bearing (ultimate)

Yield Bearing Allowable

$Byd := Ff + ncd \cdot dcd \cdot txf \cdot Fbry3$	$Byd = 75882 \cdot lb$	Twisting force allowed before Dart saddles yield in bearing (yield)
$Byb1 := ncb \cdot dcb \cdot tmatf \cdot Fbry4 \cdot ff$	$Byb1 = 37184 \cdot lb$	Twisting force allowed before Bell fwd saddles yield in bearing (yield)
$Byb2 := ncb \cdot dcb \cdot tmata \cdot Fbry4 \cdot ff$	$Byb2 = 46109 \cdot lb$	Twisting force allowed before Bell aft saddles yield in bearing (yield)

Margin of Safety

The above analysis shows that the Bell saddles will fail in bearing before the fasteners that hold the saddles onto the crosstubes fail. In the Dart configuration, the fasteners will fail in shear before the saddles will fail in bearing.

$MS6f := \frac{Fsd}{Byb1} - 1$	$MS6f = 1.14$	Margin of Safety - Dart fwd saddle-to-crosstube fastener failure
$MS6a := \frac{Fsd}{Byb2} - 1$	$MS6a = 0.73$	Margin of Safety - Dart aft saddle-to-crosstube fastener failure

7.4 Upper Saddle Strength Comparison

This calculation checks the strength of the saddle material through the critical cross section illustrated in Figure 5 of Reference 1. The estimates for the inertia values and the area of this cross section are also shown in the Reference section.

$Lf := \frac{Ld}{2} - ctubefwd$	$Lf = 2.61 \cdot in$	Dart forward saddle flange length
$La := \frac{Ld}{2} - ctubeaft$	$La = 2.50 \cdot in$	Dart aft saddle flange length
$CGxf := ctubefwd + 0.5 \cdot Lf$	$CGxf = 2.69 \cdot in$	Dart forward Center of Gravity of flange
$CGyf := ctubefwd + tf + \frac{trf}{2}$	$CGyf = 1.61 \cdot in$	Dart forward Center of Gravity of rib
$CGxa := ctubeaft + 0.5 \cdot La$	$CGxa = 2.75 \cdot in$	Dart aft Center of Gravity of flange
$CGya := ctubeaft + tf + \frac{tra}{2}$	$CGya = 1.72 \cdot in$	Dart aft Center of Gravity of rib

$$Isxf := \frac{\pi}{4}\cdot\left[(ctubefwd + tf)^4 - ctubefwd^4\right] + 4\cdot\left(\frac{1}{12}\cdot tf\cdot Lf^3 + tf\cdot Lf\cdot CGxf^2\right) \qquad Isxf = 15.61\cdot in^4$$

$$Isyf := \frac{\pi}{4}\cdot\left[(ctubefwd + tf)^4 - ctubefwd^4\right] + 2\cdot\left[\frac{1}{12}\cdot 1.5\cdot tw\cdot trf^3 + 1.5\cdot tw\cdot trf\cdot CGyf^2 + Lf\cdot tf\cdot\left(\frac{g}{2} + \frac{tf}{2}\right)^2\right] \qquad Isyf = 2.28\cdot in^4$$

$$Asf := \pi\cdot\left[(ctubefwd + tf)^2 - ctubefwd^2\right] + 4\cdot tf\cdot Lf + 2\cdot 1.5\cdot tw\cdot trf \qquad Asf = 3.56\cdot in^2$$

$$Isxa := \frac{\pi}{4}\cdot\left[(ctubeaft + ta)^4 - ctubeaft^4\right] + 4\cdot\left(\frac{1}{12}\cdot ta\cdot La^3 + ta\cdot La\cdot CGxa^2\right) \qquad Isxa = 21.17\cdot in^4$$

$$Isya := \frac{\pi}{4}\cdot\left[(ctubeaft + ta)^4 - ctubeaft^4\right] + 2\cdot\left[\frac{1}{12}\cdot 1.5\cdot tw\cdot tra^3 + 1.5\cdot tw\cdot tra\cdot CGya^2 + Lf\cdot tf\cdot\left(\frac{g}{2} + \frac{tf}{2}\right)^2\right] \qquad Isya = 3.59\cdot in^4$$

$$Asa := \pi\cdot\left[(ctubeaft + ta)^2 - ctubefwd^2\right] + 4\cdot ta\cdot La + 2\cdot 1.5\cdot tw\cdot tra \qquad Asa = 5.75\cdot in^2$$

The inertias of the Bell saddles are based on the circular cross section shown in Figure 3 of Reference 1.

$Ibf := \frac{1}{4}\cdot\pi\cdot\left[(ctubefwd + tmatf)^4 - ctubefwd^4\right]$	$Ibf = 1.2\cdot in^4$	Bell forward saddle inertia
$Abf := \pi\cdot\left[(ctubefwd + tmatf)^2 - ctubefwd^2\right]$	$Abf = 1.14\cdot in^2$	Bell forward saddle area
$Iba := \frac{1}{4}\cdot\pi\cdot\left[(ctubeaft + tmata)^4 - ctubeaft^4\right]$	$Iba = 1.92\cdot in^4$	Bell aft saddle inertia
$Aba := \pi\cdot\left[(ctubeaft + tmata)^2 - ctubeaft^2\right]$	$Aba = 1.54\cdot in^2$	Bell aft saddle area

<u>Ultimate Bending Allowable</u>

$Mduf1 := \frac{Ftu3\cdot Isxf\cdot 2}{Ld}$	$Mduf1 = 163938\cdot lb\cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mduf2 := \frac{Ftu3\cdot Isyf}{ctubefwd + txf}$	$Mduf2 = 58008\cdot lb\cdot in$	Dart inboard-outboard bending allowable for fwd saddle
$Mdua1 := \frac{Ftu3\cdot Isxa\cdot 2}{Ld}$	$Mdua1 = 222239\cdot lb\cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mdua2 := \frac{Ftu3\cdot Isya}{ctubeaft + txa}$	$Mdua2 = 83148\cdot lb\cdot in$	Dart inboard-outboard bending allowable for aft saddle
$Mbuf := \frac{Ftu4\cdot Ibf\cdot ff}{ctubefwd + tmatf}$	$Mbuf = 45392\cdot lb\cdot in$	Bell bending allowable for forward saddle
$Mbua := \frac{Ftu4\cdot Iba\cdot ff}{ctubeaft + tmata}$	$Mbua = 66227\cdot lb\cdot in$	Bell bending allowable for aft saddle
$MS7f := \frac{Mduf1}{Mbuf} - 1$	$MS7f = 2.61$	Margin of Safety - Dart fwd-aft bending allowable for forward saddle (ultimate)
$MS7a := \frac{Mdua1}{Mbua} - 1$	$MS7a = 2.36$	Margin of Safety - Dart fwd-aft bending allowable for aft saddle (ultimate)
$MS8f := \frac{Mduf2}{Mbuf} - 1$	$MS8f = 0.28$	Margin of Safety - Dart inboard-outboard bending allowable for forward saddle (ultimate)
$MS8a := \frac{Mdua2}{Mbua} - 1$	$MS8a = 0.26$	Margin of Safety - Dart inboard-outboard bending allowable for aft saddle (ultimate)

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Compressive Yield Bending Allowable

$Mdycf1 := \frac{Fcy3 \cdot Isxf \cdot 2}{Ld}$	$Mdycf1 = 136615 \cdot lb \cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mdycf2 := \frac{Fcy3 \cdot Isyf}{ctubefwd + txf}$	$Mdycf2 = 48340 \cdot lb \cdot in$	Dart inboard-outboard bending allowable for fwd saddle
$Mdyca1 := \frac{Fcy3 \cdot Isxa \cdot 2}{Ld}$	$Mdyca1 = 185199 \cdot lb \cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mdyca2 := \frac{Fcy3 \cdot Isya}{ctubeaft + txa}$	$Mdyca2 = 69290 \cdot lb \cdot in$	Dart inboard-outboard bending allowable for aft saddle
$Mbyf := \frac{Fcy4 \cdot Ibf \cdot ff}{ctubefwd + tmatf}$	$Mbyf = 41202 \cdot lb \cdot in$	Bell bending allowable for forward saddle
$Mbya := \frac{Fcy4 \cdot Iba \cdot ff}{ctubeaft + tmata}$	$Mbya = 60114 \cdot lb \cdot in$	Bell bending allowable for aft saddle
$MS9f := \frac{Mdycf1}{Mbyf} - 1$	$MS9f = 2.32$	Margin of Safety - Dart fwd-aft bending allowable for forward saddle (compressive yield)
$MS9a := \frac{Mdyca1}{Mbya} - 1$	$MS9a = 2.08$	Margin of Safety - Dart fwd-aft bending allowable for aft saddle (compressive yield)
$MS10f := \frac{Mdycf2}{Mbyf} - 1$	$MS10f = 0.17$	Margin of Safety - Dart inboard-outboard bending allowable for forward saddle (compressive yield)
$MS10a := \frac{Mdyca2}{Mbya} - 1$	$MS10a = 0.15$	Margin of Safety - Dart inboard-outboard bending allowable for aft saddle (compressive yield)

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Tensile Yield Bending Allowable

$Mdytf1 := \frac{Fty3 \cdot Isxf \cdot 2}{Ld}$	$Mdytf1 = 136615 \cdot lb \cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mdytf2 := \frac{Fty3 \cdot Isyf}{ctubefwd + txf}$	$Mdytf2 = 48340 \cdot lb \cdot in$	Dart inboard-outboard bending allowable for fwd saddle
$Mdyta1 := \frac{Fty3 \cdot Isxa \cdot 2}{Ld}$	$Mdyta1 = 185199 \cdot lb \cdot in$	Dart fwd-aft bending allowable for forward saddle
$Mdyta2 := \frac{Fty3 \cdot Isya}{ctubeaft + txa}$	$Mdyta2 = 69290 \cdot lb \cdot in$	Dart inboard-outboard bending allowable for aft saddle

$Mbyf := \dfrac{Fty4 \cdot Ibf \cdot ff}{ctubefwd + tmatf}$	$Mbyf = 39107 \cdot lb \cdot in$	Bell bending allowable for forward saddle
$Mbya := \dfrac{Fty4 \cdot Iba \cdot ff}{ctubeaft + tmata}$	$Mbya = 57057 \cdot lb \cdot in$	Bell bending allowable for aft saddle
$MS11f := \dfrac{Mdytf1}{Mbyf} - 1$	$MS11f = 2.49$	Margin of Safety - Dart fwd-aft bending allowable for forward saddle (tensile yield)
$MS11a := \dfrac{Mdyta1}{Mbya} - 1$	$MS11a = 2.25$	Margin of Safety - Dart fwd-aft bending allowable for aft saddle (tensile yield)
$MS12f := \dfrac{Mdytf2}{Mbyf} - 1$	$MS12f = 0.24$	Margin of Safety - Dart inboard-outboard bending allowable for forward saddle (tensile yield)
$MS12a := \dfrac{Mdyta2}{Mbya} - 1$	$MS12a = 0.21$	Margin of Safety - Dart inboard-outboard bending allowable for aft saddle (tensile yield)

Shear Allowable

$Fsudf := Fsu3 \cdot Asf$	$Fsudf = 96209 \cdot lb$	Dart shear force allowable
$Fsuda := Fsu3 \cdot Asa$	$Fsuda = 155204 \cdot lb$	Dart shear force allowable
$Fsubf := Fsu4 \cdot Abf \cdot ff$	$Fsubf = 40101 \cdot lb$	Bell shear force allowable for forward saddle
$Fsuba := Fsu4 \cdot Aba \cdot ff$	$Fsuba = 54078 \cdot lb$	Bell shear force allowable for aft saddle
$MS13f := \dfrac{Fsudf}{Fsubf} - 1$	$MS13f = 1.4$	Margin of Safety - Dart shear allowable for fwd saddle
$MS13a := \dfrac{Fsuda}{Fsuba} - 1$	$MS13a = 1.87$	Margin of Safety - Dart shear allowable for aft saddle

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8.0 Skidtube Comparisons

8.1 General Information

It is an important aspect of skidtube design that the structure maintain its shape to preserve inertial properties. Experience has shown that round tubes lose at least 10% of their primary inertial properties under bending conditions.

$fb := 0.90$

Secondly, the analysis of section 7.4 shows that Dart saddles are significantly stiffer than Bell saddles in the principal skidtube bending direction therefore increasing the rigidity of the supports in a beam analysis. In terms of bending moments resulting from a centrally located load P over a beam of length L, a pinned-pinned beam must be designed for bending moments of the magnitude PL/4 while a fixed-fixed beam must be designed for bending moments of the magnitude PL/8. The allowable bending moments in a pinned-pinned beam are therefore half of the allowable bending moments in fixed-fixed beam. Because of the difference in end conditions between a Dart skidtube and a Bell skidtube, a reduction factor will be applied to the allowable bending moments in Bell skidtubes.

$fe := 0.90$